Prenatal Exposure To An E L F-Rotating Magnetic Field And Subsequent Increase In Conditioned Suppression[1]

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Male rats were exposed prenatally to a .5 Hz, .5-3 to 10-30 gauss rotating magnetic field (RMF), comparable in frequency (but of slightly higher magnitude) to extreme low frequency magnetic fields associated with some geomagnetic and meteorological disturbances. In three replications, RMF-exposed rats showed significantly greater suppression in response rate (relative to controls) during the 4-min conditioned stimulus (CS) preceding a .5 mA, .5 sec shock in a conditioned suppression procedure. The RMF-exposed animals showed the greatest suppression, relative to controls, during the first few shock exposures. Subsequent CS-shock pairings were followed by similar suppression in both groups. RMF-exposed rats also showed more initial suppression during the first presentation of the CS without shock. These findings are consistent with previous open field and Sidman avoidance data that suggest that the RMF-exposed animals are more reactive to novel and aversive stimuli, and underline the importance of understanding the effects of everyday geophysical-meteorological variables upon development and consequent behavioral changes.

Exposure of adults to extreme low frequency (ELF) and very low frequency (VLF) electromagnetic fields, with intensities similar to and slightly higher than those which occur during some meteorological and geomagnetic disturbances, have been shown to affect behavior (Altmann, 1969; Friedman, Becker & Bachman, 1967; König, 1962; Persinger, Ossenkopp, & Glavin, in press; Reiter, 1964; Wever, 1967). The precise characteristics of these natural disturbances and their consequences upon behavior are discussed elsewhere (Ossenkopp, Koltek, & Persinger, 1972). Recently, it has been argued that susceptibility to the effects of these fields should be increased during prenatal development (Persinger, 1969). Rats exposed during their entire prenatal development to a .5 Hz, .5 to 30 gauss rotating magnetic field (RMF) showed

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significantly less ambulatory behavior and greater defecation in an open field test (Persinger, 1969), fewer lever presses in a Sidman avoidance situation (Persinger & Foster, 1970), and heavier but more variable thyroid weights (Ossenkopp, Koltek, & Persinger, 1972), than controls. Since the behavioral data suggested that, relative to controls, RMF-exposed rats exhibit more "freezing" behavior in the presence of novel or aversive stimuli, we decided to test such rats on a conditioned suppression paradigm. In this procedure (Estes & Skinner, 1941), a conditioned stimulus (CS) followed by an unavoidable shock (UCS) is superimposed upon a baseline of responding maintained by positive reinforcement. This procedure is well established (Brady & Hunt, 1955; Sidman, 1960), and produces a suppression of responding during the CS.

Method

Subjects

In three experiments, 30 70-day-old Holtzman strain male albino rats (*Rattus norvegicus*) were used as subjects. Sixteen of the rats had been randomly selected from 8 litters that had been exposed continuously during their prenatal development to a .5 Hz RMF, with intensities ranging from .5-30 gauss, whereas the remaining 14 male rats were randomly selected from 8 litters that had been prenatally exposed to control conditions. In experiment I, four experimental rats had been exposed to 5 to 10 gauss. In experiment II, four rats had been exposed to a 3 to 30 gauss field, whereas another 4 had been exposed to a .5 to 3 gauss RMF. The 4 experimental rats in experiment III had been exposed to a .5 to 20 gauss RMF and nursed by control mothers. In the three experiments, there were 4, 6, and 4 control rats, respectively.

Apparatus

Rotating Magnetic Field Apparatus

The RMF was created by 2 horseshoe magnets, rotating in opposite directions about their major axes at 30 rpm via an electric motor (Fig. 1). The poles of the RMF, rotating clockwise with respect to magnetic north, were aligned in a N-S direction in Winnipeg, Canada. More precise details can be found elsewhere (Persinger, 1969).

Operant Chamber

A commercial operant chamber, with a lever mounted on one wall, was used in all 3 experiments. A constant power stimulator delivered shock via a scrambling device to

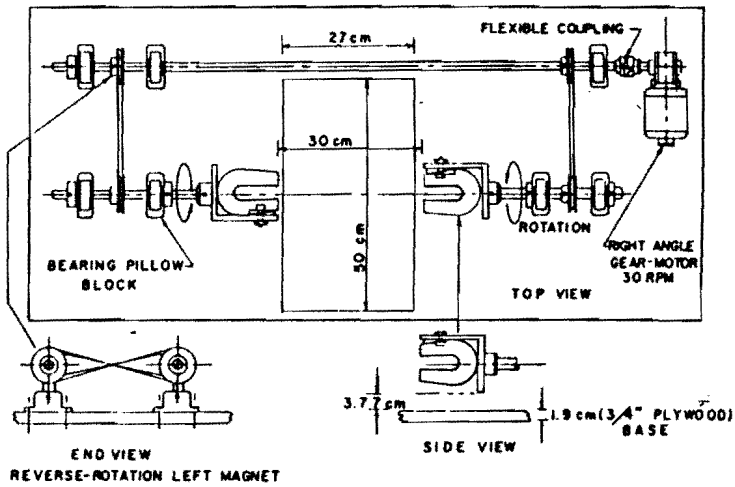

Fig. 1. The rotating magnetic field (RMF) apparatus. Exposure intensities were obtained by partitioning the marked rectangular exposure area between the magnets.

the grid floor of the chamber. The chamber was housed in a sound-insulated box located in a sound-insulated room; the automatic programming equipment and recording apparatus were in an adjoining room.

Procedure

Breeding and Housing Females

On the day that spermatozoa were found in the vaginal smears, the mothers of the subjects were placed into one of two 24 X 75 X 25 cm rubber tile cages, divided into compartments each. The cages were covered with 1.3 cm wire mesh. One or 2 females were placed in a compartment during different breeding periods, but the number of females in a particular compartment in both cages was the same throughout the prenatal period. One cage was placed in the RMF while the other (control) cage was placed 300 cm from the nearest magnet. During exposure lighting was continuous and water and food were freely available. At birth, the pups were removed from the experimental conditions. A more detailed description of the procedure was reported earlier (Persinger, 1969).

Conditioned Suppression

At 70 days of age the subjects were reduced to 80% free-feeding weight which was adjusted to the age of each animal throughout the experiment. Following training to press a lever for food pellets, the rats were maintained on a VI 30-sec reinforcement

schedule during 40-min daily sessions. Four to 5 days later the CS, a 4-min period during which the chamber light was off, was introduced. Two CS presentations occurred, one 8 min and the other 28 min after the beginning of each session. Four days later in experiment I and 6 days later in experiments II and III, a .5-mA, 0.5-sec electric shock delivered to the grid floor accompanied the onset of the chamber light immediately following the CS. (Two 100 msec shocks following the CS presentations were delivered one session early to all subjects in Experiment I by mistake.) From then on in experiments I and II, the UCS always followed the CS, while in experiment III the UCS followed the CS only on 2 out of every 4 sessions. (Downward arrows in Fig. 2 indicate those sessions on which the CS occurred alone; upward arrows indicate those sessions on which it was followed by shock). In experiment I the shock grids were wiped off with a damp cloth before each rat's session although, apparently, this did not prevent a steady increase in insulation due to an accumulation of urine residue across sessions. In experiments II and III the grids were rubbed with sandpaper and wiped off with a damp cloth before each rat's session.

Results

In Fig. 2, mean response suppression for each group is plotted across sessions. The suppression ratio for each subject was derived by subtracting number of responses emitted during the CS periods from number of responses emitted during the 4-min periods immediately before the CS periods, and dividing this result by the latter number. (Note that 1.00 represents complete suppression, wheras 0 indicates no suppression.) In experiment I, on the third and fourth days after the introduction of the shock, the RMF-exposed rats showed greater suppression of response rate than did controls. A t test on the difference between the groups was carried out for these sessions, and, although admittedly computed *post hoc*, it was significant at the .01 level ($t = 3.01$). No overlap existed between RMF and control groups on these sessions. In experiment II, both RMF-exposed groups showed greater suppression than did the controls, although this difference was statistically significant (on the third and fourth days after the introduction of the shock) only for the .5 to 3 gauss group ($t = 2.91$; $p < .05$). (Because of the small number of subjects in the 3 groups and variations in field intensity, we do not feel justified in concluding we have established a curvilinear relationship between field intensity and amount of suppression.) After the fifth day, the difference between RMF-exposed and control groups began to diminish. This suggests that RMF-exposed rats only initially show greater relative suppression. In experiment III, CS plus UCS was presented for 2 days; then only CS alone was presented for 2 or 3 days, etc. As noted in Fig. 2, RMF-exposed rats showed greater suppression ($t = 10.06$; $p < .01$) on the day following the first two sessions with shock. Again, as in experiment I, no overlap existed between experimental and control rats on the day of maximum effect. Subsequent presentations of shock after CS resulted in

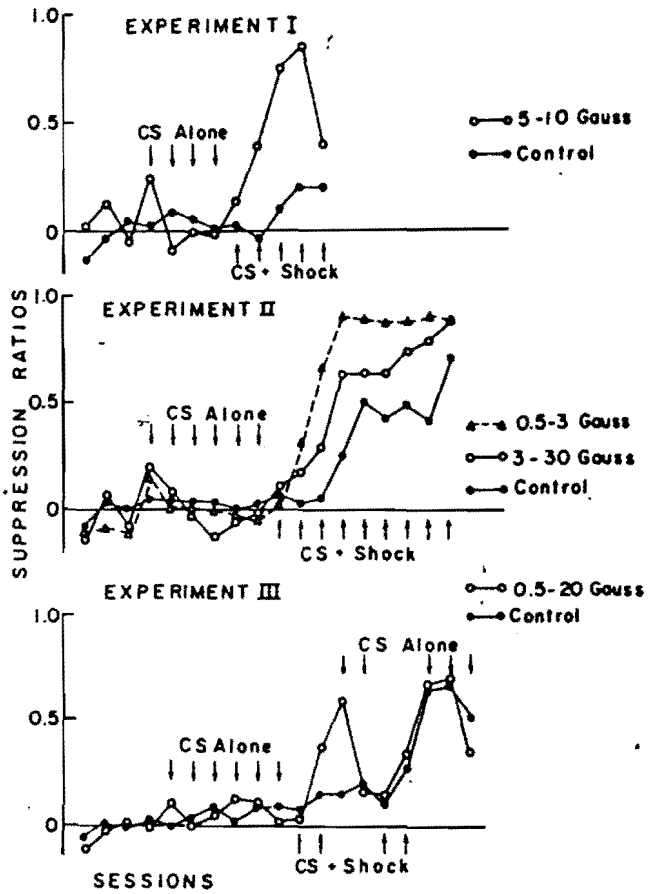

Fig. 2. Mean suppression ratios for rats exposed prenatally to the RMF (○,△) and control (●) conditions in three experiments.

similar suppression rates for both control and RMF-exposed animals. Transient suppression was noted in all 3 experiments during the first day of CS presentation without shock (see Fig. 2). This transient suppression was greater for RMF-exposed rats, although the difference was statistically significant only in experiment II ($t = 2.89; p < .05$).

Discussion

The above results are consistent with previous open field and Sidman avoidance data suggesting that RMF-exposed animals show more "freezing" behavior in the presence of novel or aversive stimuli. Since rats exposed prenatally to as little as .5 to 3 gauss also showed greater suppression than controls, the possibility is suggested that

prenatal exposure to naturally occuring ELF magnetic fields might produce similar effects. The results of this and related studies indicate the importance of understanding the effects of everyday geophysical and meteorological variables on development and behavioral changes.

Notes

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References

Altmann, G. (1969). Die physiologische Wirkung elektrischer Felder auf Organismen. *Arch. Met. Geoph. Bioklim., B., 17:* 269-290.

Brady, J. V., and Hunt, H. F. (1955). An experimental approach to the analysis of emotional behavior. *J. Psych., 40,* 313-324.

Estes, W. K., and Skinner, B. (1941). Some quantitative properties of anxiety. *J. Exp. Psych., 29:* 390-400.

Friedman, H., Becker, R. O., and Bachman, C. H. (1967). Effect of magnetic fields on reaction time performance. *Nature, 213:* 949-956.

Konig, H. L. (1962). Ueber den Einfluss besonders niederfrequenter elektrischer Vorgänge in der Atmosphäre auf die Umvelt. *Z. Angew. Bäder-u. Klimaheilk., 9:* 481-501.

Ossenkopp, K-P., Koltek, T., and Persinger, M. A. (1972). Prenatal exposure to an ELF-low intensity rotating magnetic field and increases in thyroid and testicle weights in rats. *Develop. Psychobiol., 5:* 275-285.

Persinger, M. A. (1969). Open field behavior in rats exposed prenatally to a low intensity-low frequency, rotating magnetic field. *Develop. Psychobiol., 2:* 168-171.

Persinger, M. A., and Foster, W. S. (1970). ELF rotating magnetic fields: prenatal exposure and adult behavior. *Arch. Met. Geoph. Bioklim., B. 18:* 363-369.

Persinger, M. A., Ossenkopp, K-P., and Glavin, G. (in press). Behavioral changes in adult rats exposed to ELF Magnetic fields. *Intern. J. Biometeorol.*

Reiter, R. (1963). Welche atmosphärisch-elektrischen Elemente können auf den Organismus einwirken? *Z. Angew. Bäder-u. Klimaheilk, 10:* 161-193.

Sidman, M. (1960). Normal sources of pathological behavior. *Science, 132:* 61-68.

Wever, R. (1968). Gesetzmassigkeiten der circadianen Periodik des Menschen, geprüft an der Wirkung eines schwachen elektrischen Wechselfedes. *Pflügers Arch., 302:* 97-122.